INTRODUCTION

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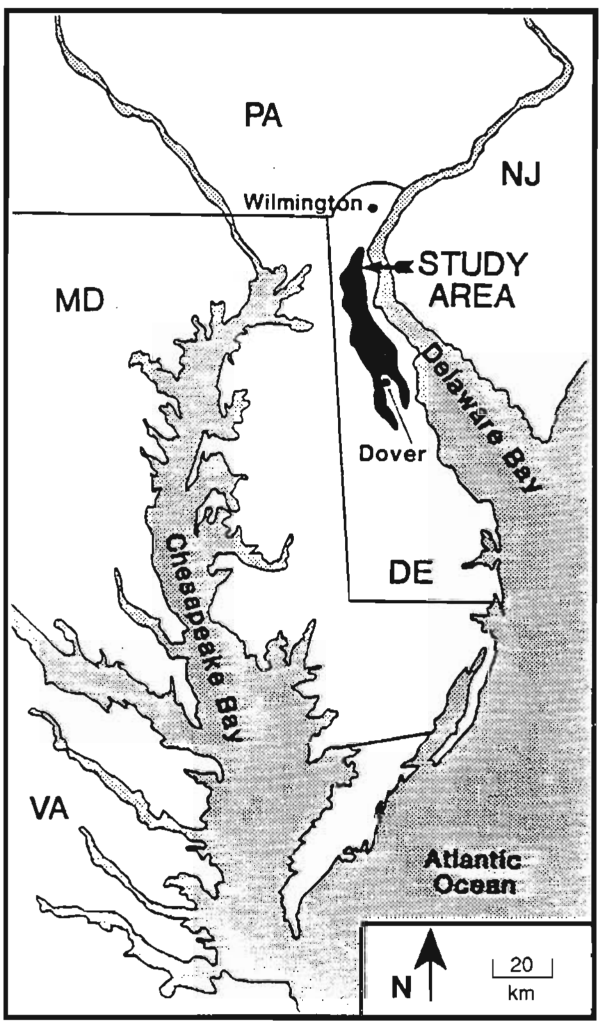
FIGURE 1
Location of State Route 1
Study Area



This report presents the results of research on past environments near archaeological sites discovered along the State Route 1 corridor (formerly designated U.S. Route 13) in New Castle and Kent counties, Delaware (Figure 1). From studies throughout the mid-Atlantic region it is known that the environments of Delaware have changed dramatically in the past (Custer 1984a:30-37; 1989). However, we do not always know what environments existed at particular places at particular times in the past. The studies included in this report provide specific information on past environments at, or near, prehistoric archaeological sites in the State Route 1 corridor. Environmental studies are important to prehistoric archaeology because almost all of Delaware's prehistoric inhabitants survived by hunting and gathering. Agriculture was not practiced until just before European colonization, so earlier people had to rely on whatever plant and animal foods could be found in the natural environment around them. If we know what kinds of resources were available in the past, then we can better understand how prehistoric people lived.

Research of past environments involves technical studies of geological and fossil evidence, such as stream and pond sediments, soils, and plant fragments and pollen. The four reports presented here provide the technical information necessary to recreate past environments in Delaware. The technical reports follow a summary of the State Route 1 archaeological project, a discussion of the methods used to study past environments, and a review of Delaware's prehistory. A synthesis of the technical studies which discusses their implications for archaeological studies of the State Route 1 corridor concludes the volume.

THE STATE ROUTE 1 PROJECT

Archaeological research into the history and prehistory of the State Route 1 corridor in Delaware began in 1982 with the preparation of a reconnaissance and planning study of a large area within which the new highway would be constructed (Custer et al. 1984). The purpose of the study was to identify and tabulate known cultural resources including historic buildings, historic archaeological sites of Delaware's early settlers, and prehistoric Native American archaeological sites that might be disturbed by highway construction. The study also used Landsat satellite photography to identify areas that were likely site locations, but had never been examined for archaeological sites (Custer Bachman, and Grettler 1986). The study was undertaken because cultural resources are protected by law under Section 106 of the National Historic Preservation Act. Archaeological research is one of the activities included in the preparation of any environmental impact statements for federally funded projects (for example, Custer and Cunningham 1986). The reconnaissance and planning survey of the State Route 1 corridor documented 150 prehistoric sites and over 750 historic sites.

After the initial planning study, more specific and detailed archaeological research was undertaken in selected areas of the highway corridor where the earlier study had indicated high densities of sites and a high potential for additional archaeological sites (Custer and Bachman 1986a; Custer, Bachman, and Grettler 1986). The study documented the relationships between archaeological sites and environmental variables in an effort to better understand patterns of prehistoric land use. For example, 90% of all prehistoric sites in the project area are within 100 m (328 ft.) of water (Custer and Bachman 1986a:131). In contrast, only half of the historic sites in the project area are within 200 m (660 ft.) of fresh water (Custer and Bachman 1986a:173). Field survey located 425 new (previously unrecorded) prehistoric archaeological sites and tests of the predictive model showed that it worked well (Custer, Bachman, and Grettler 1986:175). The studies by Newby, Webb, and Webb, reported here, were initiated during this phase of research (Bachman 1987:100; Custer and Bachman 1986a:83).

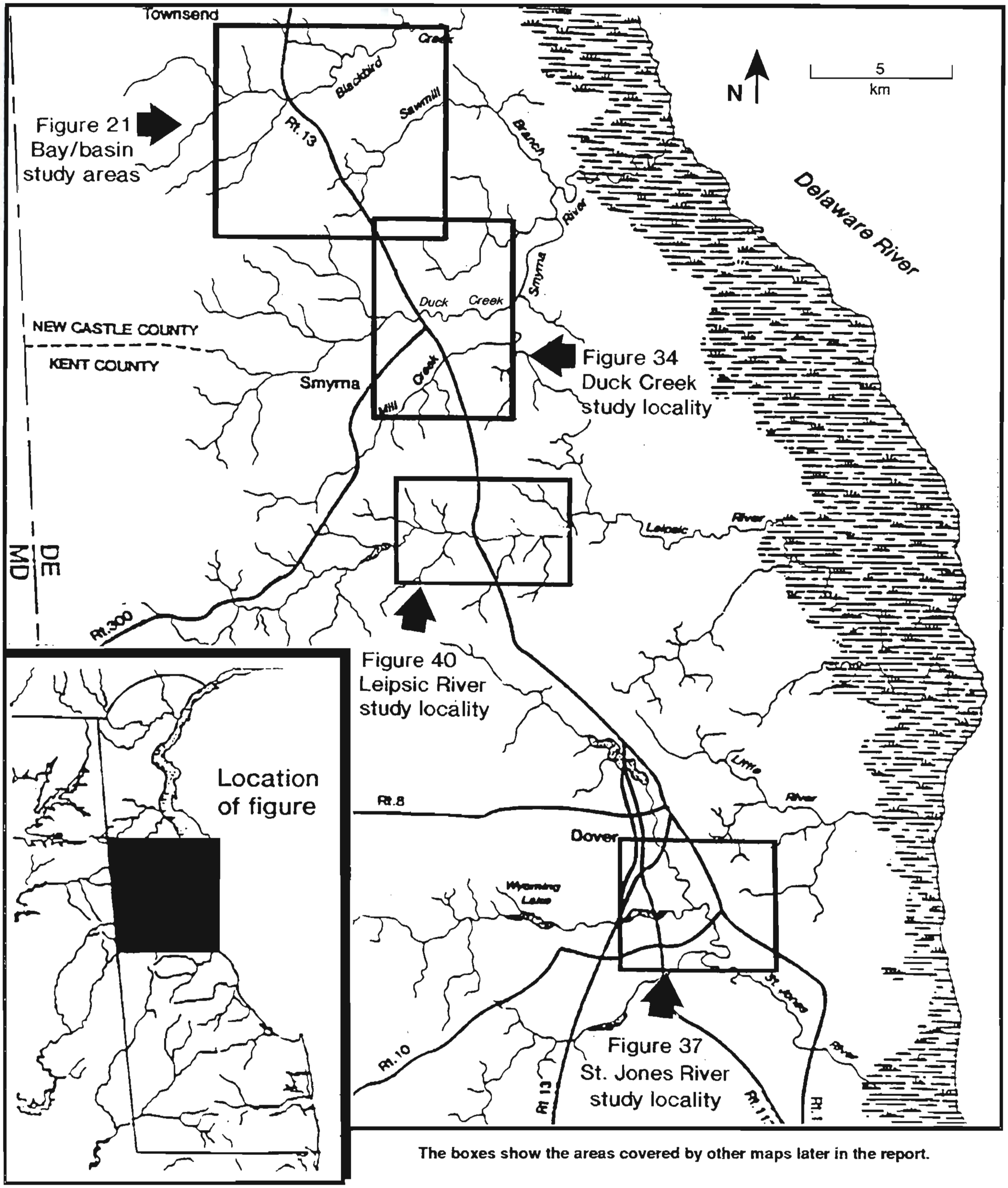
Based on the results of the preliminary planning and environmental impact studies, the Delaware Department of Transportation (DelDOT) selected specific highway alignments from within the larger study area (Figure 2). The next phase of archaeological research was the investigation of the specific alignments before highway construction began. Field survey was designed to identify archaeological sites within the proposed highway alignments and assess the potential significance of the sites (Custer, Bachman, and Grettler 1987). The details of the surveys are reported by Bachman, Grettler, and Custer (1988) and Hodny, Bachman, and Custer (1989).

After surveys identify archaeological sites that may be significant, further test excavations are carried out (for example, Grettler et al. 1991). Testing entails controlled excavations to determine if the sites are well preserved, contain especially important information, or are associated with a particular historic person. If there is no way to avoid destroying significant archaeological sites during highway construction, then full scale excavations are undertaken to record the important information about the past contained in the ground. The environmental studies by Rogers and Pizzuto, and by Brush, (this volume) were carried out in conjunction with excavations at significant prehistoric archaeological sites in the path of highway construction. Excavations at these sites (Figure 3) were completed during the summers of 1990 and 1991. Site excavation reports are in preparation.

As documented in the reconnaissance, planning, and survey reports for the State Route 1 archaeological study (Custer et al. 1984; Custer and Bachman 1986a; Custer, Bachman, and Grettler

FIGURE 2

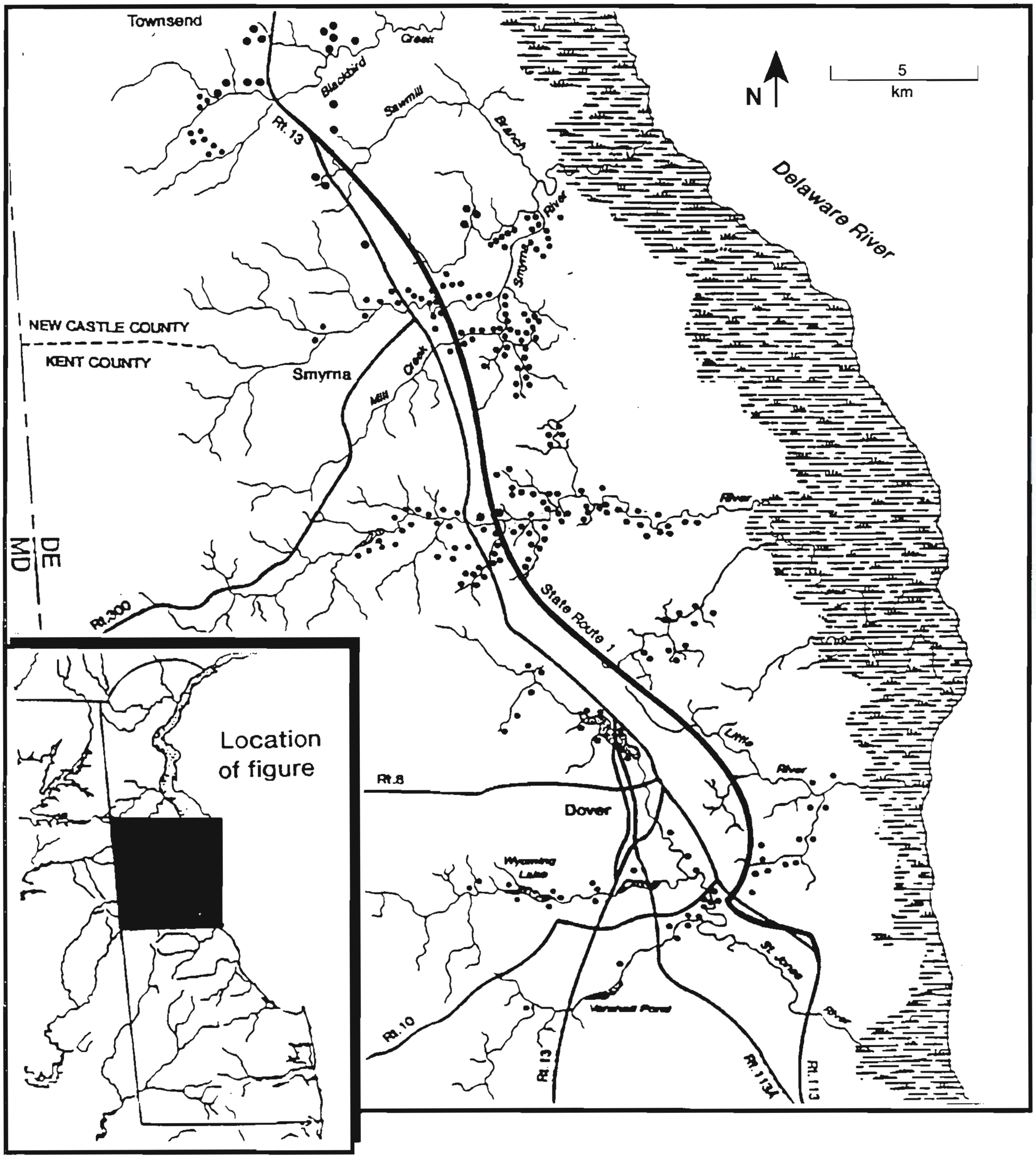
State Route 1 Corridor and Paleoenvironmental Study Localities



The boxes show the areas covered by other maps later in the report.

FIGURE 3

Prehistoric Archaeological Sites Along the State Route 1 Corridor



1986), prehistoric people were closely tied to the physical environment because they lived off the land - hunting, fishing and shell fishing, and gathering wild plant foods, such as nuts, wild rice and other seeds, berries, and edible roots and shoots (Custer 1984a). At some sites the remnants of meals are preserved in storage pits, fire places, or trash dumps, but often clues to past life styles are inferred by knowing the environment of the past at the time of occupation.

Another reason why archaeologists collaborate with specialists from other fields of research in reconstructing past environments is to understand the landscape changes that have occurred since prehistoric occupation of a site or region. Geological processes can bury or erode sediments, or shift artifacts and other remains from their original location of use or discard. In other words, archaeologists must understand how a site was formed in order to understand what the finds mean about people living in the past. Reconstructing past environments places archaeological finds within a context that is relevant to the people who lived there.

One more reason for undertaking the studies described in this report, rather than relying on studies carried out for other purposes, is that local environments are often obscured by large scale regional studies. It may be an error to extrapolate environmental studies at one locality to another; therefore, local, specific studies aimed at archaeological questions must be carried out. Furthermore, some earlier research into the environments of the Delmarva Peninsula, as discussed in a later section, have suggested that the regional data covering the Middle Atlantic coastal plain in general do not apply to some situations in Delaware (Custer 1984b; Custer and Watson 1987:87).

PALEOENVIRONMENTAL METHOD AND THEORY

A variety of techniques have been developed by geologists and ecologists for studying past environments. Geologists combine studies of sedimentary environments - places where gravels, sands, silts, or clays have been deposited - with landscape studies to determine the processes that acted in the past. Ecologists use studies of plant fossils to place trees and other plants onto the landscape. Archaeologists add people into these recreated landscapes. The following section provides a background introduction to some of the assumptions and methods used in the technical studies presented later in this volume.

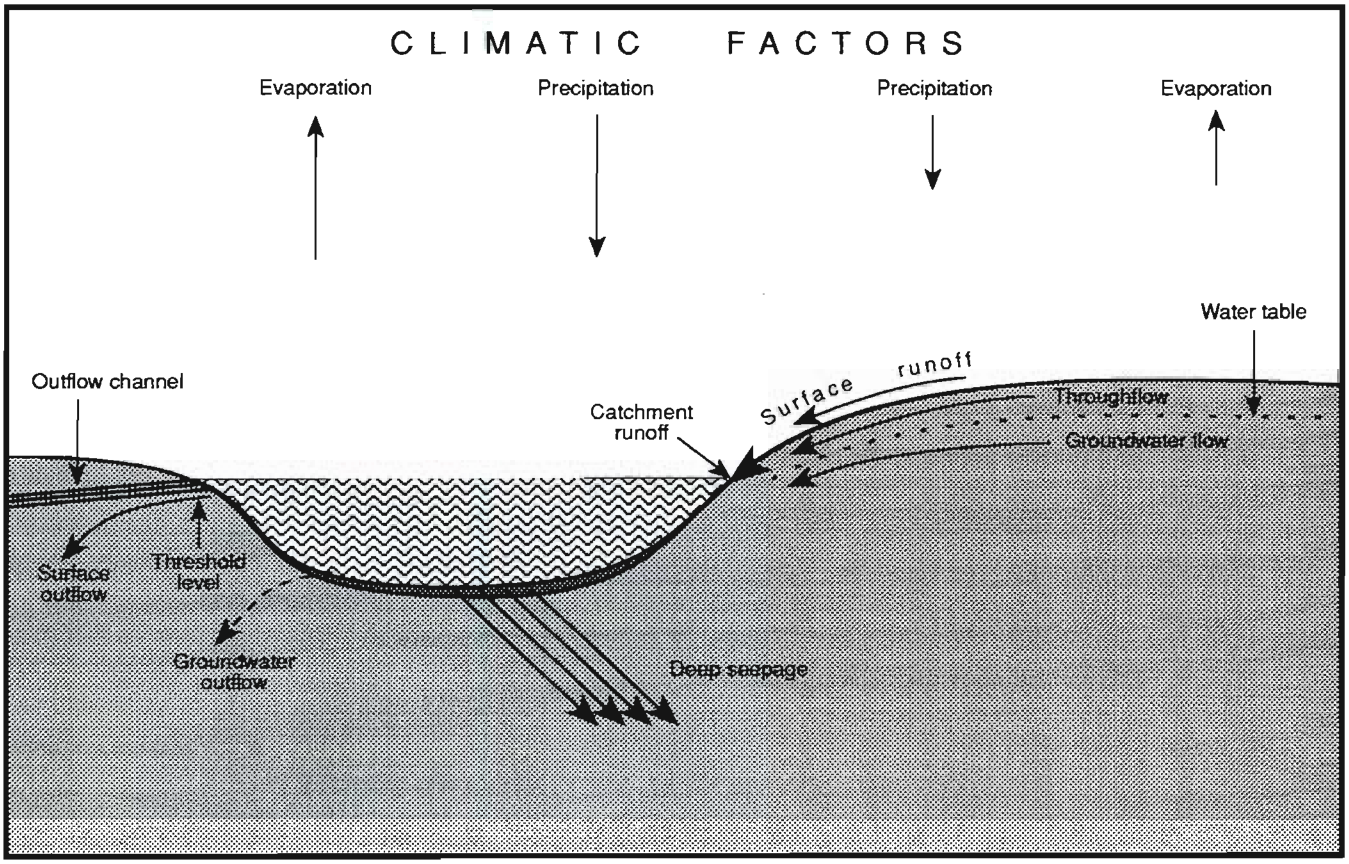
Sedimentary Analysis

Sediments are layers of mineral and organic particles laid down through the actions of water, wind, and other natural processes. Environmental reconstructions rely on the analysis and interpretation of sedimentary deposits. Where sediments accumulate over time, such as in lakes, marshes, floodplains, or at the base of slopes, a record of the environmental conditions is preserved (Reineck and Singh 1980:3-7). Environments are recreated by comparing the physical, chemical, and biological properties of sediment samples from ancient environments to modern samples from known environments (Reineck and Singh 1980:179-502). Water is the primary mover of sediments in temperate environments; however, winds also move sediments and there is evidence for this on the Delmarva Peninsula (Curry and Custer 1982; Foss et al. 1978; Ward and Bachman 1987).

Gaps in sedimentation can result from either a lack of deposition during an interval of time, or from erosion of sediments deposited earlier. Gaps in sedimentation yield environmental information because

FIGURE 4

Factors Affecting Water Levels in Lakes



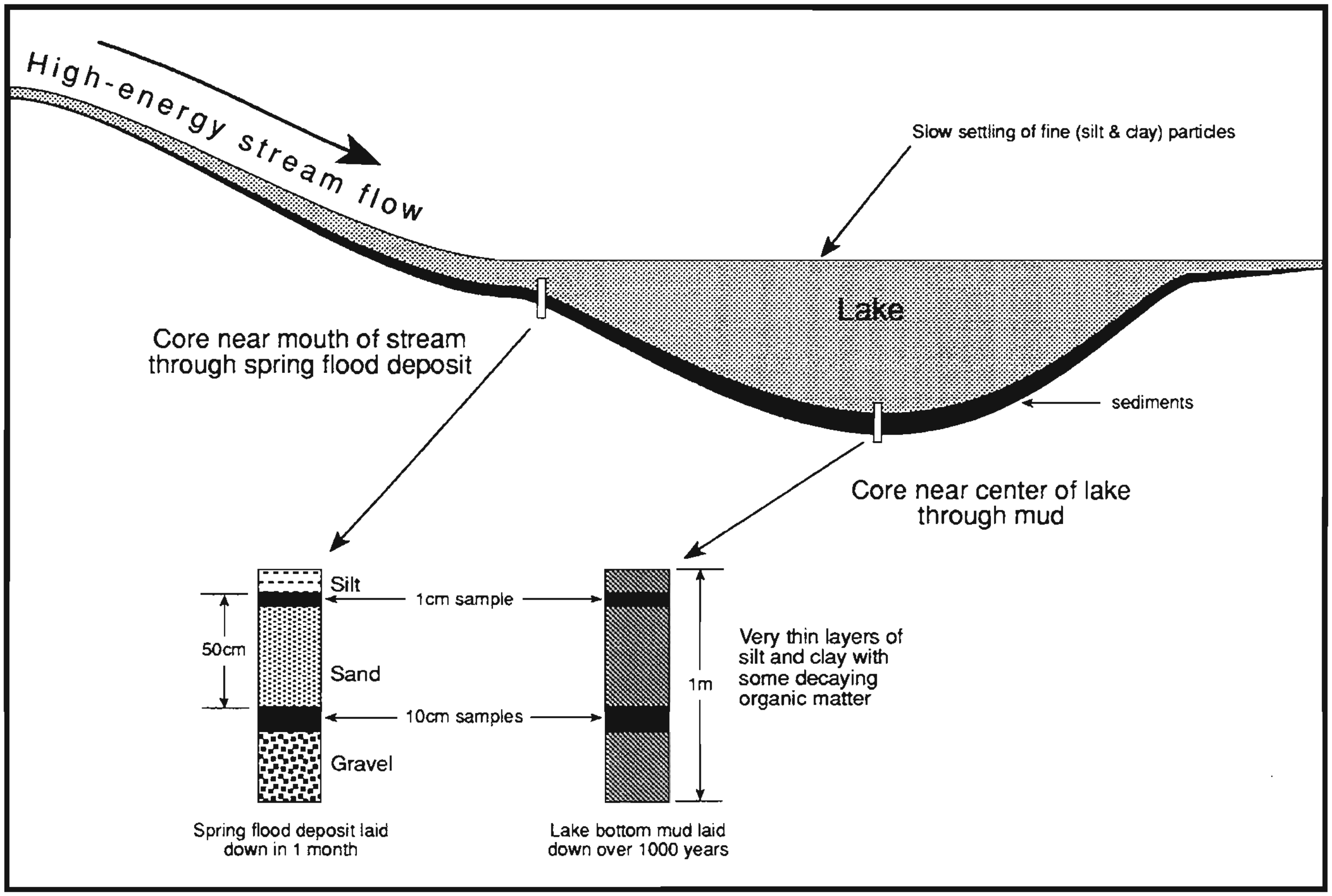
Precipitation in the form of rain and snow falls directly into the lake and runs off from the ground surrounding the lake. Other run-off enters the lake through streams flowing into the lake, or as ground water. Water is lost from the lake through outlet streams, ground water flow, seepage into bedrock, and evaporation. Lake levels are ultimately controlled by the ratio of precipitation and evaporation. (After Dearing and Foster 1986)

periods of time without accumulation suggest different environmental conditions than periods of deposition. For example, a pond dries up either because its water source has been diverted or the climate has become drier (Figure 4). Studies of fossil pollen, discussed later, are usually carried out on lake muds because lakes receive a relatively constant and continuous supply of organic sediments, such as decaying plant matter, or mineral sediments, such as sand and silt, washed in off the slopes of the surrounding landscape or carried in by streams.

The rate at which sediments are deposited affects the time resolution of environmental reconstructions. Rapid deposition, such as sand and mud deposited by spring flooding, can yield detailed records of vegetation because less time is represented by each sample of sediment and closely-spaced samples are separated by shorter time intervals. Where deposition is slow, like at the bottom of a lake, each sample includes a longer period of time and closely-spaced samples are further apart in time (Figure 5).

In rivers and lakes different types of sediments are deposited depending on the speed of waters movements, so a sediment deposit can record changes in water flow. However, erosional episodes are common in river deposits because river channels are active and move as precipitation and run-off vary and material is eroded and deposited within the stream channel.

FIGURE 5
Sediment Sampling and Sediment Accumulation Rates



The same size sample from sediments laid down under different conditions will represent different amounts of time. The spacing of samples within a core also affects the time resolution of the sampling.

Another factor influencing streams on the Delaware coastal plain is sea level (Kraft 1971). Since the end of the last ice age about 14,000 years ago sea level along the Atlantic coast has generally risen (Belknap and Kraft 1977; Fletcher 1988). As sea level has risen the lower reaches of streams and rivers have been progressively drowned by marine waters. Tides that influence the mouths and lower channels of streams can carry mud upstream and also introduce other chemical and biological actions that influence sediment deposition. For example, marine organisms that feed by filtering water excrete pellets of mud that can act like grains of sand until they break apart later. Also when fresh and salt water mix together in estuaries silts and clays stick together and act like larger particles (Kraft 1971; Reineck and Singh 1980:315-320). Thus, recreating environments based on river deposits is more difficult than for lake deposits. When geologists select a location for sediment study, they try to find a place where only one process at a time has been acting.

Geological Cross Sections. Paleoenvironmental studies are best conducted by constructing profiles, or transects, across the landscape. Cross-sections show the horizontal and vertical variability in deposits at a locality (for example, see Figures 30, 49, or 57). Transects of cores can be connected to create a three dimensional representation of sediment accumulations. Thus, the process of sedimentary analysis for recreating prehistoric environments involves a sequence of steps:

1) describe and characterize the sediments in a core, excavation, or natural exposure;

2) analyze and relate the sediments to modern analogs that identify the environment in which the sample was deposited;

3) determine the dates of deposition;

4) correlate the sequences of sediments from different locations to create cross-sections;

5) relate the local sequence to regional sequences and events.

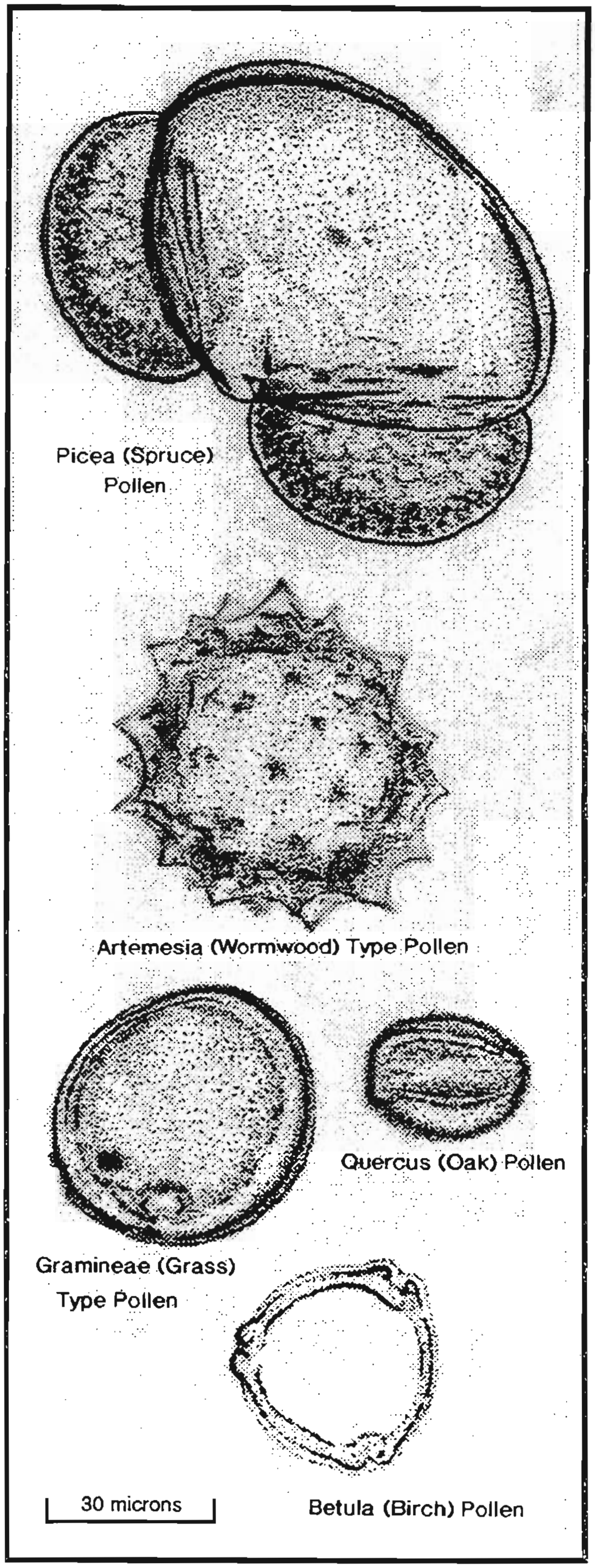
Step two above might include the study of fossils, both visible and microscopic, within the sediments. Many types of organic remains are found preserved in sediments, including seeds, pollen, plant fragments, diatoms and plankton, insect remains, fungal spores, and sometimes fish and other bones. Chemical or magnetic studies can also yield useful information depending on the goals of the research and the sediment characteristics of the study site. Knowledge of modern environments provides the means for determining the environments represented by ancient sediments.

Pollen Analysis

Pollen analysis is one of the most powerful tools for reconstructing prehistoric environments. All flowering plants produce pollen during their reproductive cycle. Pollen is the male gamete that combines with the female ovum to produce seeds (Birks and Birks 1980:177-179; Faegri and Iversen 1975:18). Pollen is microscopic ranging in size from about 5 microns to about 200 microns (1 thousandth to 5 hundredths of an inch). Pollen of different plants can have distinctive shapes and surface features (Figure 6). However, some plant groups produce pollen that cannot be easily separated. For example, pollen of spruce, fir, and pine can be distinguished from one another, but pollen of black, white, and red spruce are too similar to tell apart.

FIGURE 6

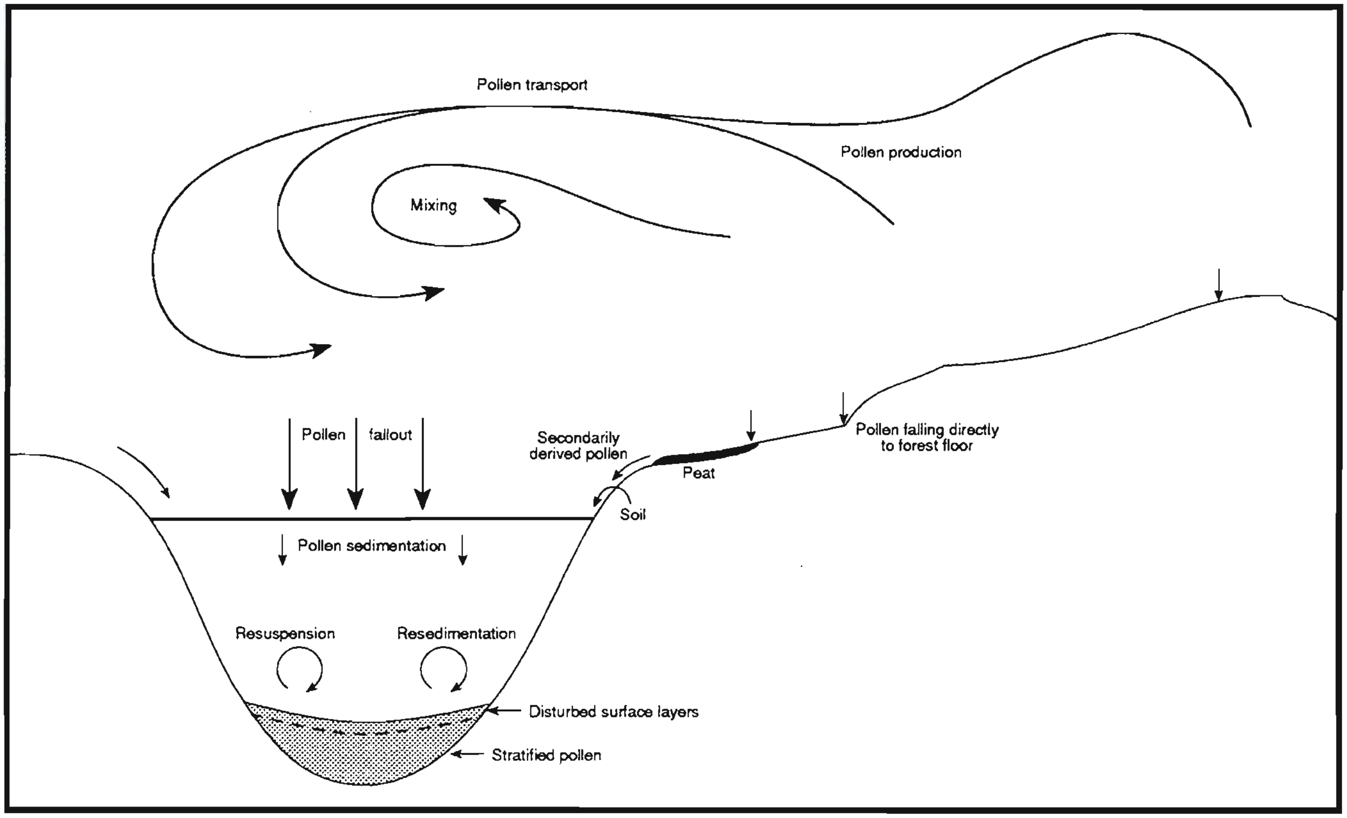
Typical Pollen Grains



(Based on photomicrographs in Moore and Webb 1978) The variations in form and structure of the pollen shell allow identification of different plants and trees.

FIGURE 7

Production and Dispersal of Pollen Grains



Most pollen grains that are deposited in lake sediments are from plants that are wind pollinated. Pollen falls onto the lake surface or is carried in by rain. After pollen is incorporated into the sediments on the lake bottom, water movements--due to waves or currents--can disturb the stratigraphy. (After Delcourt and Delcourt 1987a; and Moore and Webb 1978).

The pollen of many kinds of plants is spread by wind; while other plants rely on insects for pollination. Most plants with colorful, fragrant, and showy flowers are insect pollinated and their pollen is sticky. Most woody plants, including trees and shrubs, are wind pollinated and produce large quantities of pollen in the spring (as those of us with hay fever are well aware). Pollen dispersal by wind is a complex process (Birks and Birks 1980:179-183; Jacobson and Bradshaw 1981; Prentice 1986). Some falls directly to the ground; some is carried by winds below the leaf canopy of the forest; and some is carried aloft above the trees (Figure 7). The type of vegetation on the landscape can influence how pollen is carried by the wind. For example, winds close to the ground in a dense forest are not as strong as those on an open prairie. The shapes and sizes of pollen grains affect how far they can be carried by winds. For example, corn pollen is round and heavy and usually falls very close to the corn plants; however, pine pollen has light-weight bladders that keep it up in the atmosphere where it can be widely dispersed by winds. One final factor that has to be considered in pollen analysis is that different kinds of plants produce different amounts of pollen.

Pollen in the air eventually falls to the ground. Of course, some pollen finds its way to the female flowers of the same type of plant to produce a new generation of seeds. Excess pollen either deteriorates and is destroyed, or is preserved in favorable environments. Pollen grains are composed of a complex organic compound that is one of the most resistant substances known (Birks and Birks 1981:187-188; Fagrei and Iversen 1975:23). Sporopollenin, the substance that forms the outer shell of the pollen grain, is virtually a natural plastic. However, extended exposure to air (oxidation) will destroy pollen. Rapid burial, or deposition in a wet environment, can preserve pollen. Therefore, to use fossil pollen to study past environments, it is necessary to find locations, such as lakes or bogs, where pollen has accumulated with mineral and organic sediments over time.

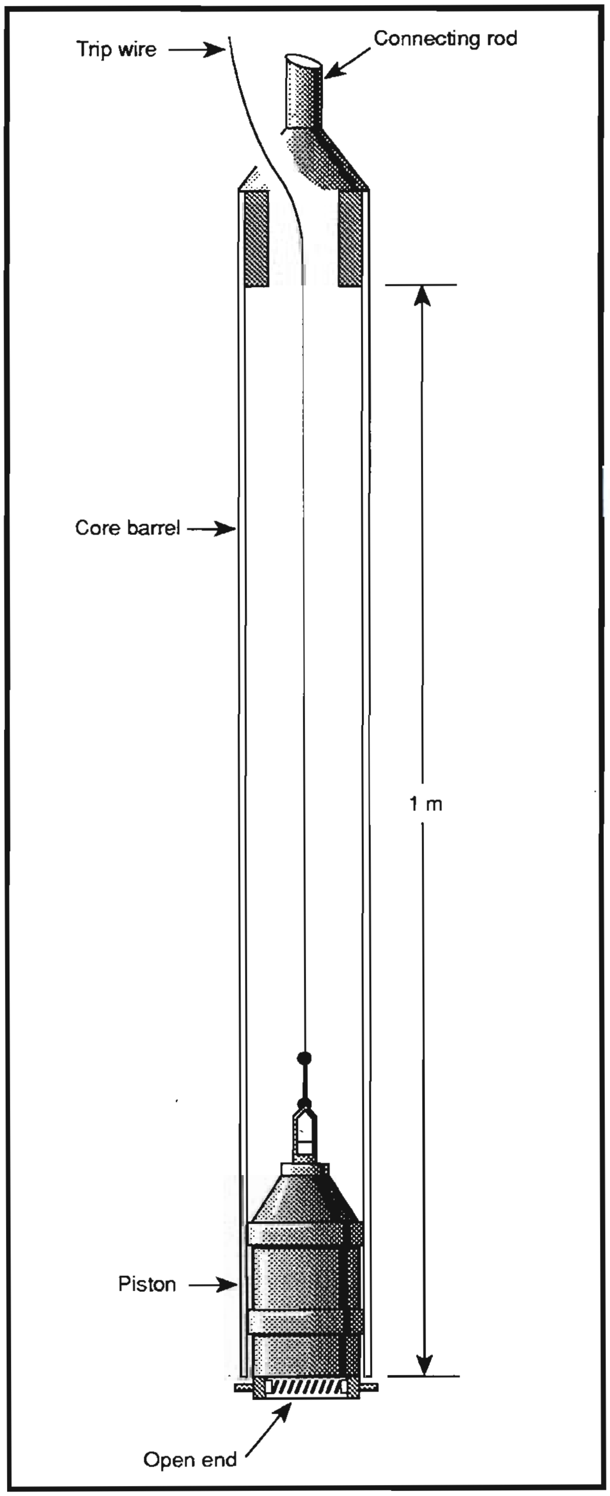
Pollen can be preserved in soils; however, mechanical, chemical, and biological action can degrade or destroy pollen so that a biased picture of vegetation can result (Dimbleby 1985:1-26; Havinga 1971; King 1975). In addition, pollen deposited at different times in the past can be mixed in the soil profile (Dimbleby 1985:1-20). Pollen data from soils are thus difficult to interpret. Nonetheless, pollen from soils can provide some useful information in certain cases (Dimbleby 1985). Pollen has been found in the soil filling prehistoric fire, house, and storage pits in Delaware (Thomas 1981).

The basic assumption of pollen analysis is that the types of pollen deposited at a particular place are representative of the range of plants growing in the area at the time (Birks and Birks 1980:156-157; Fagrei and Iversen 1975:123-127). The great quantity of pollen and its mixing in the atmosphere before deposition are assumed to yield a pollen assemblage that is characteristic of the type of forest or other vegetation (for example, prairie, wetland, tundra) that produced the pollen. Therefore, changes in pollen through time represent changes in vegetation through time, which in turn reflect climate changes, as well as other factors that affect the vegetation of a region.

Although some pollen is transported great distances in the upper atmosphere and deposited far from its source, most pollen is deposited close to its source. The type of location chosen for study will affect the ways in which the fossil pollen represents the vegetation around the site (Jacobson and Bradshaw 1981; Pennington 1979). In any pollen sequence there will be regional pollen from the plants growing for miles around the site as well as local pollen from plants growing at the site. A small

FIGURE 8

Livingstone Piston Corer



The corer is a metal tube fitted with a piston. The corer is lowered to the lake bottom from a boat or other platform on the lake surface. The trip wire holds the piston in place while the core barrel is forced into the lake mud by downward pressure on the connecting rod. The piston forms a vacuum in the core barrel so that the lake mud can be brought to the surface. The lake mud can then be pushed back out of the core barrel and packed for transport to the laboratory.

site, such as a pond one acre in area, will reflect the vegetation of a small region because the proportion of pollen from plants close by will be greater than the proportion of pollen from plants far away. On the other hand, a large lake of several hundred acres size, for example, gathers pollen from a larger region and the amount of pollen from plants close to the lake will be small compared to the amount from plants further from the lake (Jacobson and Bradshaw 1981). Also a very small site, such as a small bog hollow under a canopy of trees, will emphasize the local pollen over the regional input because pollen from far away will be carried past the site by winds above the treetops.

Since wet environments are best for pollen preservation, lake muds or marsh peats are sought for study. Hollow metal or plastic tubes (Figure 8) pushed into the lake bottom or marsh and then pulled back out recover a core from the sediment deposit. Pollen is extracted from the core by taking small volumes of mud at intervals along the core. An exotic pollen type (Eucolyptus pollen is often used in North America), or a slurry of microscopic plastic spheres, is added to the sample of mud in known quantities. The sample is then screened to remove large debris and treated with a variety of strong acids and other chemicals to leave only the pollen grains (Faegri and Iversen 1975; Pearsall 1989). A sample of only one cubic centimeter can contain hundreds of thousands of pollen grains. Pollen grain types are counted while scanning microscope slides and examining individual pollen grains at 400 times magnification, or greater. Three hundred or more pollen grains must be counted to get a statistically significant sample of the major pollen types (Birks and Birks 1980).

Changes in pollen through time can be compared through three different measures calculated from the pollen counts on each sample. First, the percentage of each pollen type relative to other pollen types can be plotted by time, or depth in the core, on a series of graphs to form a pollen diagram (see Newby, Webb, and Webb in this volume). On this type of pollen diagram, for example, if the percentage of oak pollen increases from one sample to the next, then the percentages of other types of pollen must decrease. The second measure can be calculated if the exotic pollen or marker grains (plastic spheres) are counted along with the pollen in each sample. The numbers of pollen grains per unit of volume in each sample of sediment (pollen concentration) can then be calculated. The pollen concentration is an absolute measure because the concentration of one pollen type is not affected by the concentration of other types. Finally, if absolute dates can be assigned to the core samples through radiocarbon dating, or other absolute dating techniques, then the pollen accumulation rate (number of pollen grains per square centimeter per year) can be calculated. Brush (this volume) bases her interpretations of prehistoric environments on the pollen accumulation rate (sometimes referred to as the pollen influx) of cores through marshes.

The pollen study in this volume by Newby, Webb and Webb focuses on very small ponds. Thus the emphasis is on the vegetation near to the ponds, rather than on vegetation at distances away from the ponds. The study by Brush, reported in this volume, was carried out on cores from the margins of free-flowing streams; therefore, some of the pollen could have been transported by the stream, as well as by winds. It is often difficult to interpret pollen from river and stream deposits because there may be gaps in the sequences and some pollen may be eroded and redeposited from earlier deposits upstream. Nonetheless, the local vegetation is emphasized by Brush's use of the pollen accumulation rate, rather than pollen percentages.

The local character of the environmental information provided by the studies presented in this report is what makes them useful and important to archaeologists studying the prehistoric human habitations (archaeological sites) nearby. Knowledgé of the local environment can help explain why people chose to live at a particular place and what types of environments they exploited.

TABLE 1

Geologic Time Scale*

Years Before Present	Epoch		Period
0			
	Holocene		
10,000			Quaternary
	Pleistocene		
1,600,000			
	Pliocene	Neogene	
5,300,000			
	Miocene		
23,700,000			Tertiary
	Oligocene	Paleogene	
36,600,000			
	Eocene		
57,800,000			
	Paleocene		
66,400,000			

* Based on DNAG 1983 Time Scale, Geological Society of America.

Plant Macrofossils

Plant fragments (often referred to as macrofossils to distinguish them from microscopic plant fossils, such as pollen) are pieces of, segments of, or whole individual plants, including leaves, stems, bark fragments, twigs, seeds and so forth (Mannion 1986). Large plant fragments are not transported far by wind and water in comparison to pollen grains. Pollen grains do not provide direct evidence of plants growing at a particular location because pollen is transported to the place where it is preserved - sometimes for great distances. Plant macrofossils, on the other hand, unequivocally show the presence of particular plants growing around a lake basin or within the drainage basin of a stream.

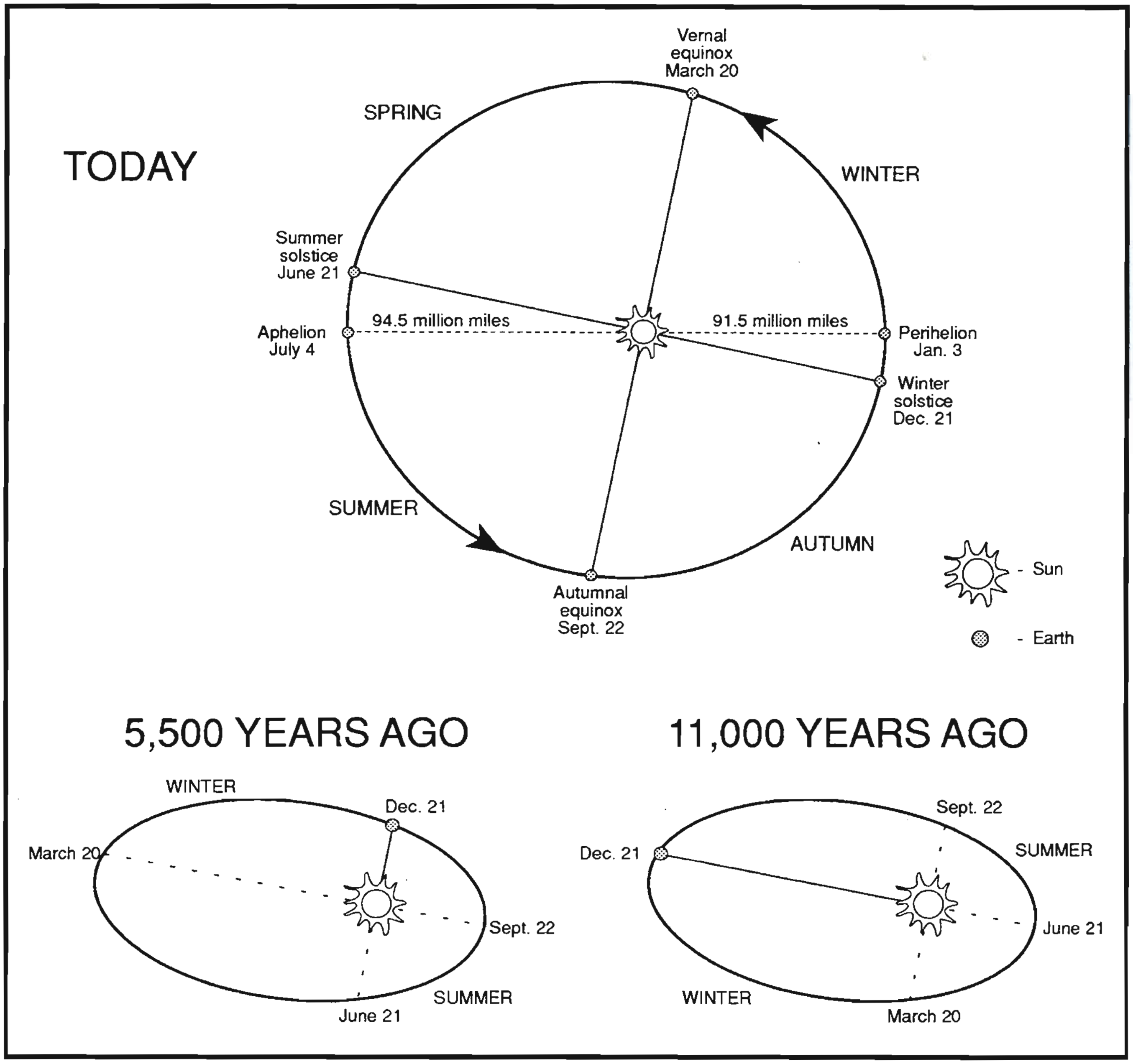
Another advantage of studying plant macrofossils is that large fragments of plants can often be identified to the species level (for example, white oak), while most pollen can only be narrowed to the genus level (for example, oak of some type). Plant macrofossils require a suitable environment for preservation, and as with pollen, rapid deposition and a wet environment increase the chances of preservation. However, the shear volume of pollen produced by plants and the durable pollen shell make pollen grains a much more common indicator of past vegetation. Brush's study of past environments, in this volume, combines the evidence of fossil pollen with plant macrofossils from the same cores. The plant macrofossil information can be used to help interpret the pollen data.

REGIONAL PALEOENVIRONMENTAL AND CLIMATE CHANGE

Geologists refer to the past 2 million years as the Quaternary period (Table 1). The hallmark of the Quaternary is the onset of cold conditions that caused the extinction of many marine plankton (Berggren

FIGURE 9

Variations in the Earth's Orbit

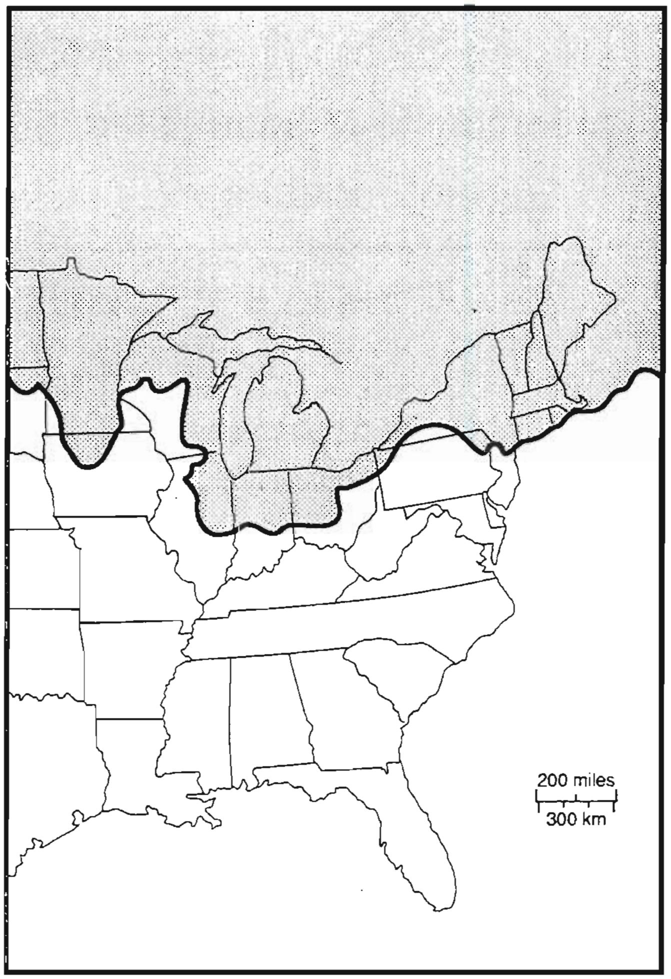


The Earth slowly wobbles on its axis as it moves around the sun. The wobble causes the relationship between the seasons of the year and the distance from the Earth to the sun to change through time. The result is that the amount of sunlight reaching the surface of the Earth changes over time (From Imbrie and Imbrie 1979).

1980). The Quaternary is divided into two parts: the Holocene is the last 10,000 years, while the Pleistocene comprises the remainder of the Quaternary. The Pleistocene is the time of the ice ages (Flint 1971). Contrary to popular perception there have been many more than four continental glaciations. During the Pleistocene, there were approximately 20 "ice ages" occurring in cycles averaging 100,000 years (Imbrie and Imbrie 1979; Ruddiman and Wright 1987). The major causes for the build up of ice on the continents are cycles of change in the earth's orbit around the sun and a wobble in the earth's spin (Figure 9; Imbrie and Imbrie 1979). North American archaeologists are concerned with only the most recent glacial age because there is no good evidence of people in the New World until the end of the last glaciation (Dincauze 1984; Jelinek 1992; Lynch 1990; West 1983).

FIGURE 10

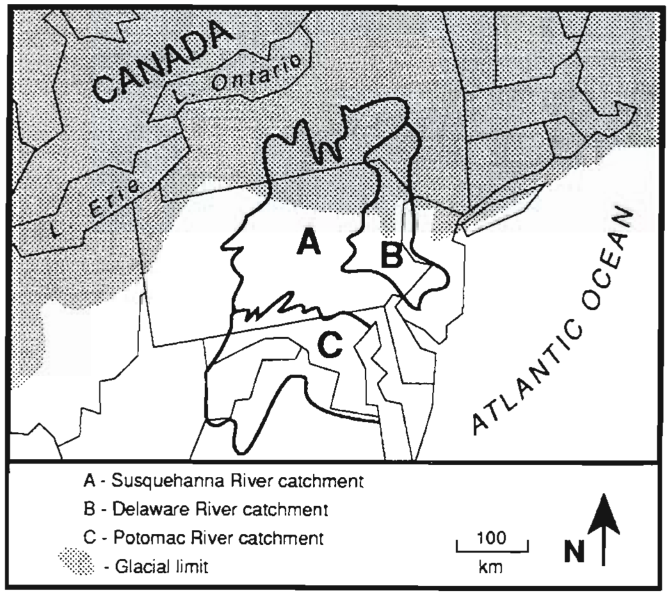
The Extent of Ice During the Last Glacial Maximum and Vegetation Zones



The maximum extent of the ice sheet between 21,000 and 14,000 B.P. (from Denton and Hughes 1981). Vegetation zones were pushed south by the colder climate, and sea level was lower due to the water locked into ice on land.

FIGURE 11

Delaware and Susquehanna River Drainages



The relationship between the maximum extent of glacial ice and the drainages of the Delaware, Susquehanna, and Potomac Rivers. The Delaware and Susquehanna Rivers carried melt water away from the ice sheet margins when melting began about 14,000 B.P.

The Last Glacial Maximum and Deglaciation

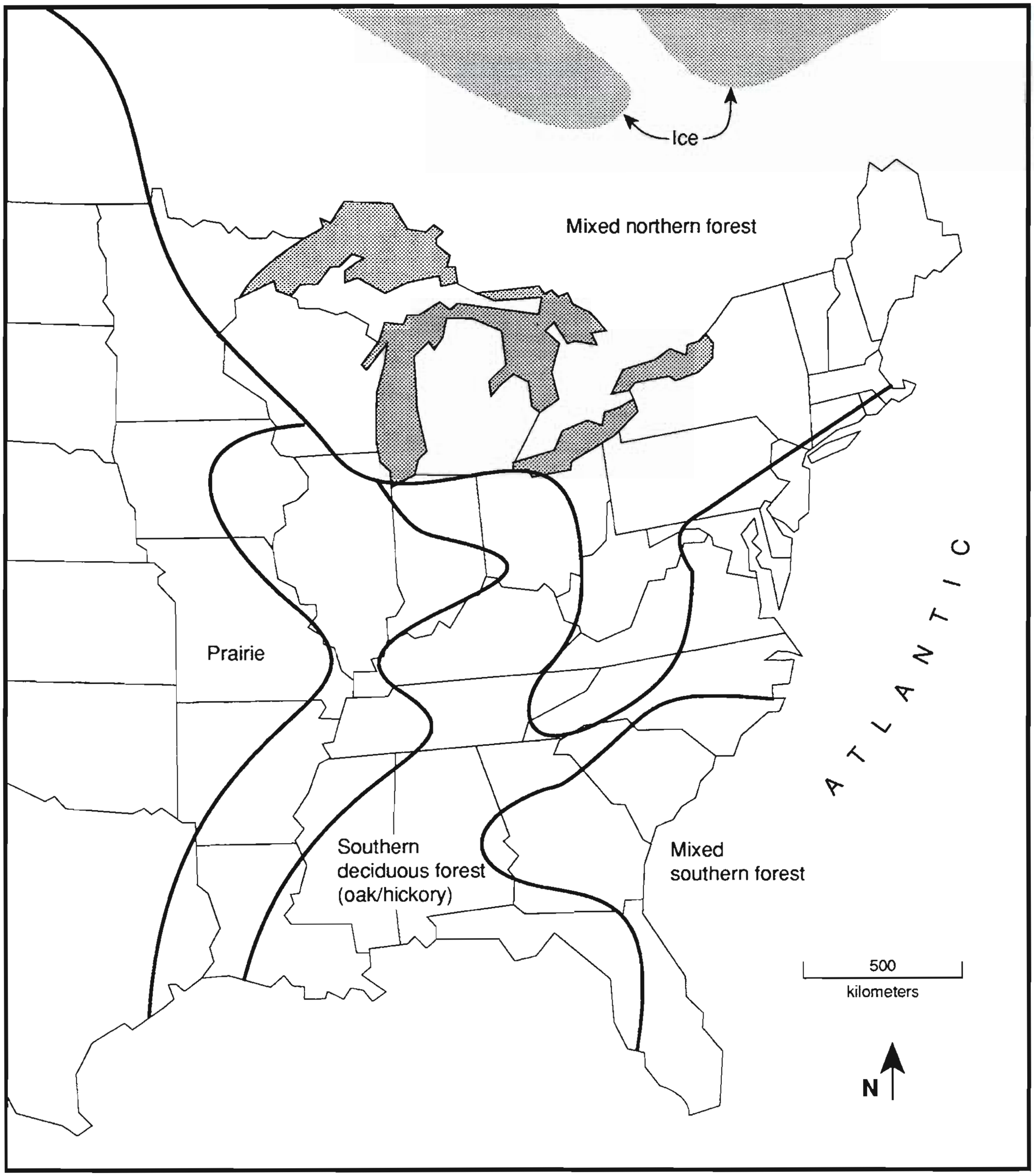
Glaciers are ice that is thick enough to flow at the bottom under the pressure of its own weight. At the maximum extent of the last glaciation, from about 21,000 to 14,000 years before present (BP), a dome of ice more than a mile thick centered over Hudson Bay and extended across all of eastern Canada and New England and reached as far south as northern Pennsylvania (Mayewski, Denton, and Hughes 1981). The ice margin stretched across the Dakotas and merged with ice covering the Rocky Mountains (Figure 10).

Climate zones were pushed south during the glacial maximum so that arctic tundra stretched up to 60 miles south of the ice (Clark and Ciolkosz 1988; Watts 1983) (Figure 10). Spruce and northern pine trees grew in Georgia (Watts 1980; Whitehead 1973) and Louisiana (Delcourt et al. 1980). Sea level was lowered over 300 feet so that the continental shelves were almost completely exposed because the ice sheets kept water on land instead of in the oceans (Bloom 1985).

The ice sheets began to melt and break up starting about 14,000 BP. Melting was very rapid as sea level rise brought marine waters into contact with the ice (Denton and Hughes 1981). Large volumes of cold water raged down rivers, including the Susquehanna and Delaware Rivers (Baker 1983:116), draining

FIGURE 12

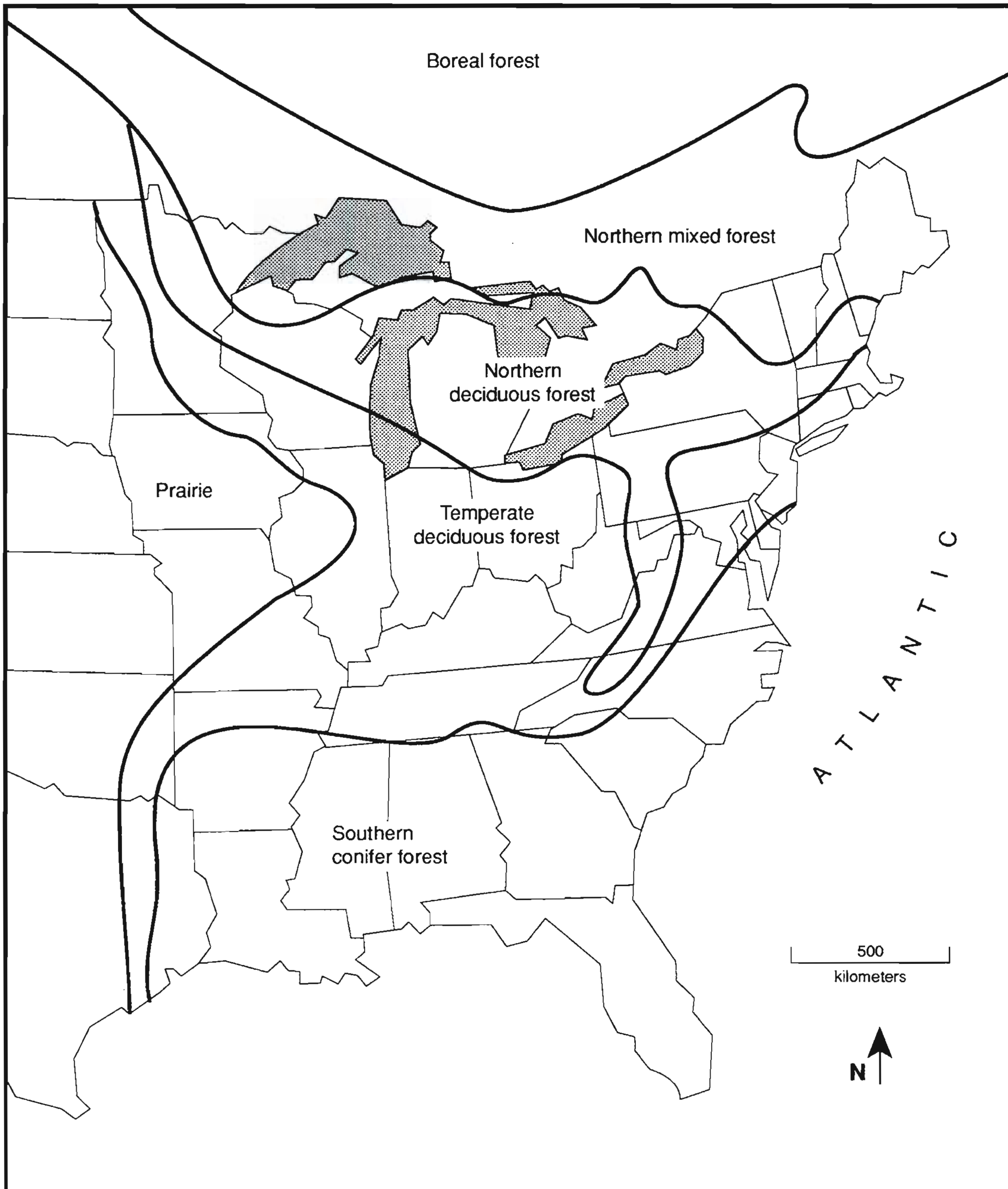
Vegetation Zones 7,000 Years Ago



(Based on Denton and Hughes 1981; and Jacobson, Webb, and Grimm 1987). The climate of the eastern United States was substantially warmer and drier 7,000 years ago than it is today. One result of the warmer climate was the eastward expansion of the prairies that now cover the Great Plains.

FIGURE 13

Present Vegetation Zones



(Based on Delcourt and Delcourt 1987a; and Jacobson, Webb, and Grimm 1987).

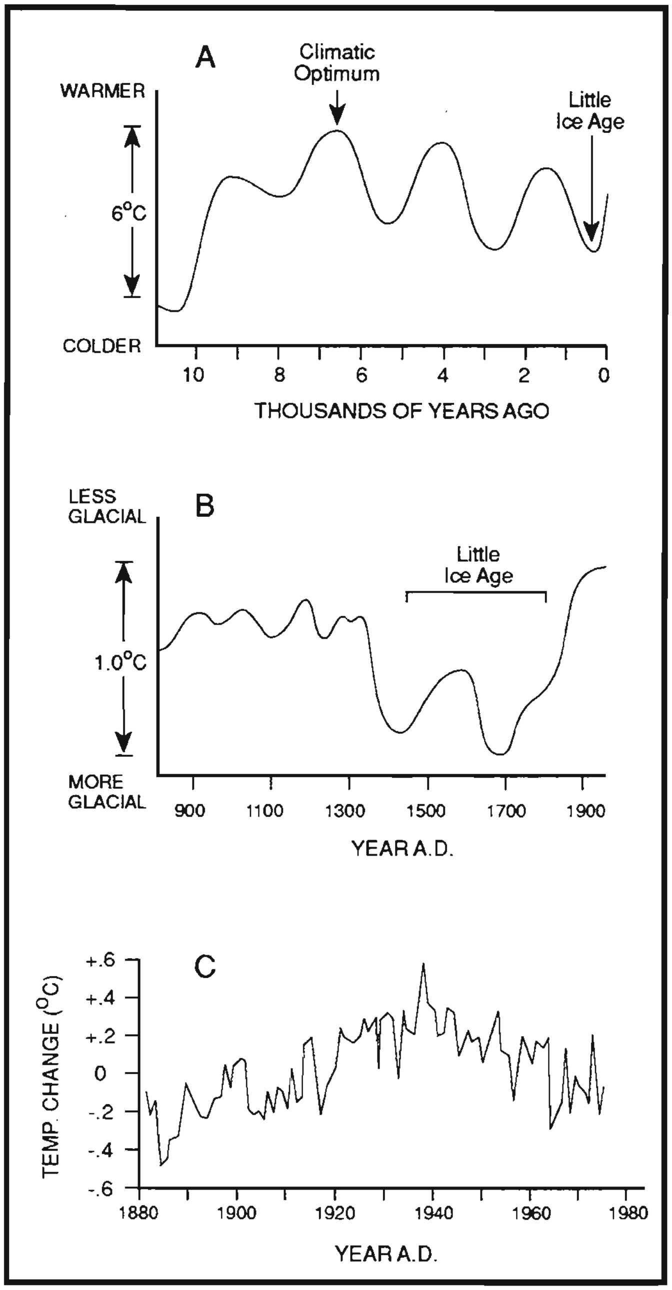
the ice sheets (Figure 11). However most melt water drained down the Mississippi and St. Lawrence Rivers from large lakes next to the retreating ice sheet (Teller 1990). The "Great Lakes" are remnants of these much larger lakes. The last glacial ice finally disappeared over northern Canada about 6000 BP (Mayewski, Denton, and Hughes 1981).

Plants species responded individually to the climate changes that melted the ice, but in general vegetation zones shifted northwards rapidly as the ice retreated (Delcourt and Delcourt 1987a,1987b; Gaudreau 1988; Webb, Bartlein, and Kutzbach 1987). Increased solar warmth in northern latitudes summers, reaching a maximum at 9000 BP (Kutzbach 1987:426), led to an eastward expansion of prairie vegetation (Figure 12), until about 7000 BP (Delcourt and Delcourt 1984). Solar radiation was 8% greater than at present in July, but winters were cooler; therefore, seasonal variation was greater at 9000 BP (Kutzbach 1987:426). At the same time boreal forest species (for example, spruce, fir, and northern pines) retreated far to the north of their present ranges (Jacobson, Webb, and Grimm 1987).

Since 9000 BP (11,000-7000 BP), conditions have gradually approached modern values and vegetation has shifted accordingly (Delcourt and Delcourt 1984; Gaudreau 1988; Watts 1983). Prairie shifted west and the boreal forest adopted its present configuration across Canada (Figure 13). Climate has been gradually cooling since about 9000 BP, but fluctuations have occurred (Figure 14; Denton, Hughes, and Karlen 1986) as in, for example, the "Little Ice Ages" (Grove 1988).

FIGURE 14

Climate Fluctuations Over the Last 10,000 Years



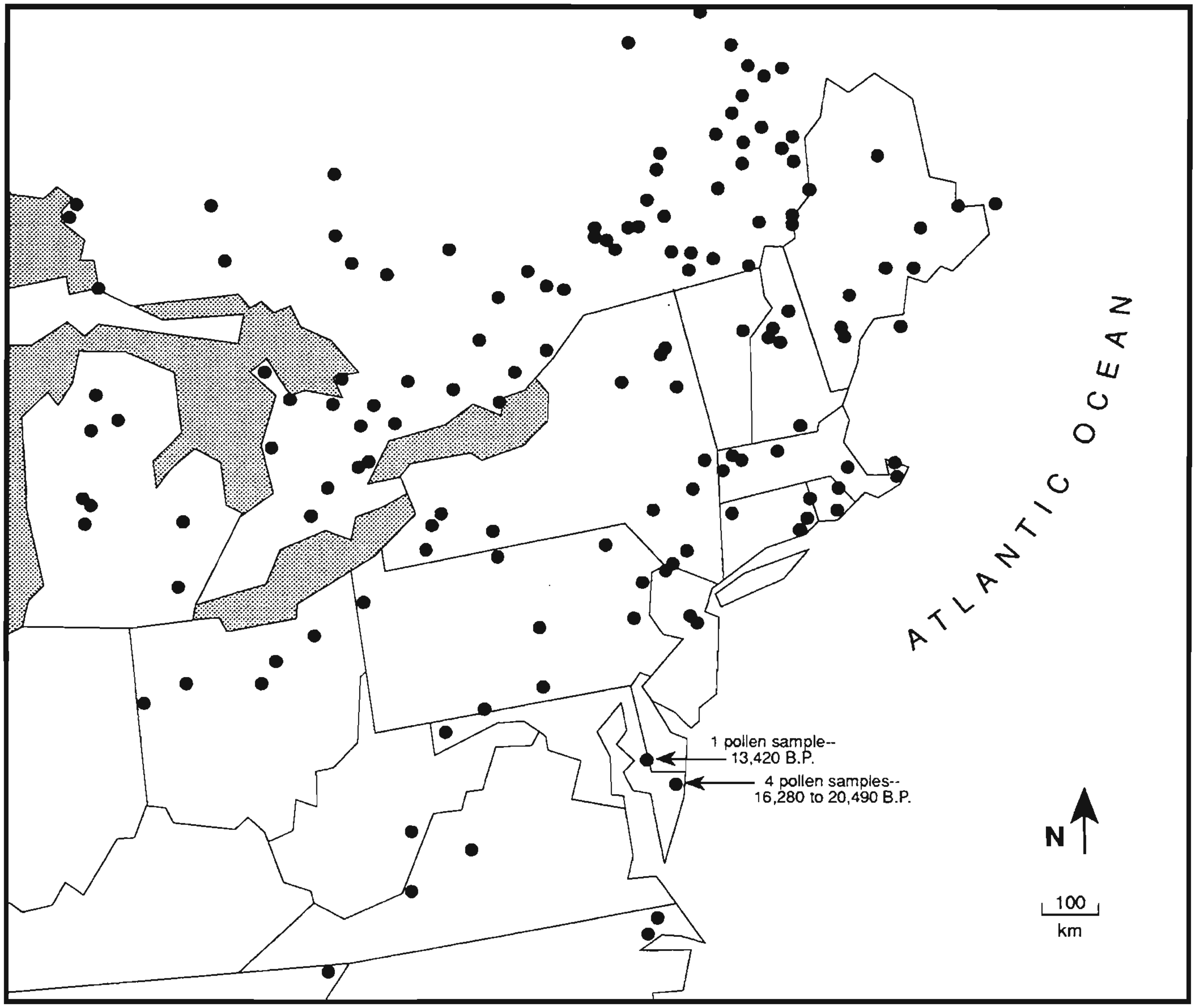
(From Imbrie and Imbrie 1979) A: Over the last 10,000 years; B: Over the last 1000 years; C: Over the last 100 years.

Holocene Environments

This section will concentrate on the Middle Atlantic region of the United States to provide the context for the State Route 1 environmental studies presented in this volume. The discussion is based on recently published

FIGURE 15

Eastern U.S. Pollen Study Localities



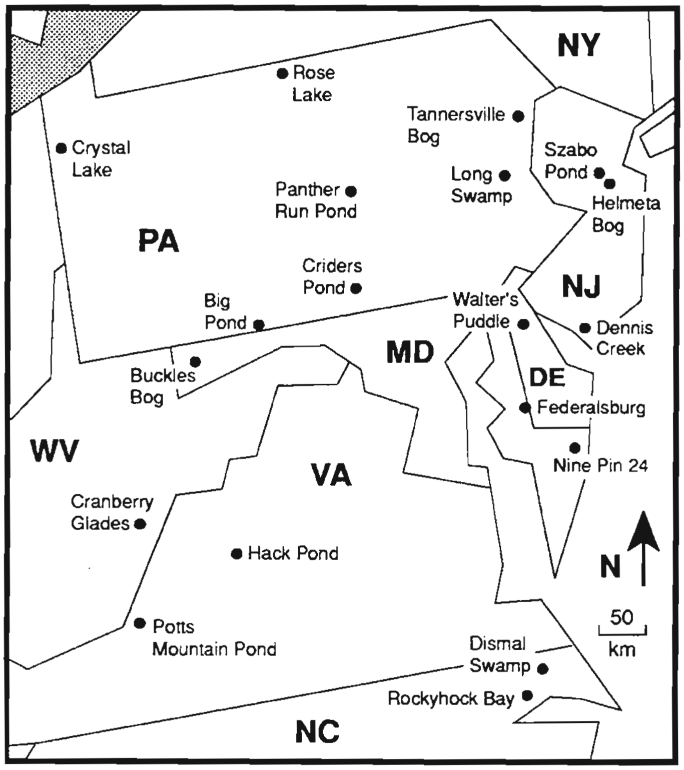
(From Gaudreau 1988) More studies have been undertaken within the area covered by ice during the last glaciation because more lakes and bogs are present.

reviews employing modern radiocarbon-dated studies of pollen and plant macrofossils. Individual ecological studies that relate to the Delmarva Peninsula are emphasized. Few ideal places for pollen studies exist south of the maximum glacial limit. Lakes that have held water throughout the last 10,000 years are rare. North of the glacial limit the scoured bedrock and irregular terrain of glacial deposits holds many lakes, and a generally cooler climate has maintained water levels. Thus, the density of pollen studies in New England and the northern Midwest is much greater than for the southern United States (Figure 15).

Complete Holocene pollen sequences nearest to the Delmarva Peninsula are from the Dismal Swamp (Whitehead 1972) in northeastern Virginia and Rockyhock Bay in northeastern North Carolina (Whitehead

FIGURE 16

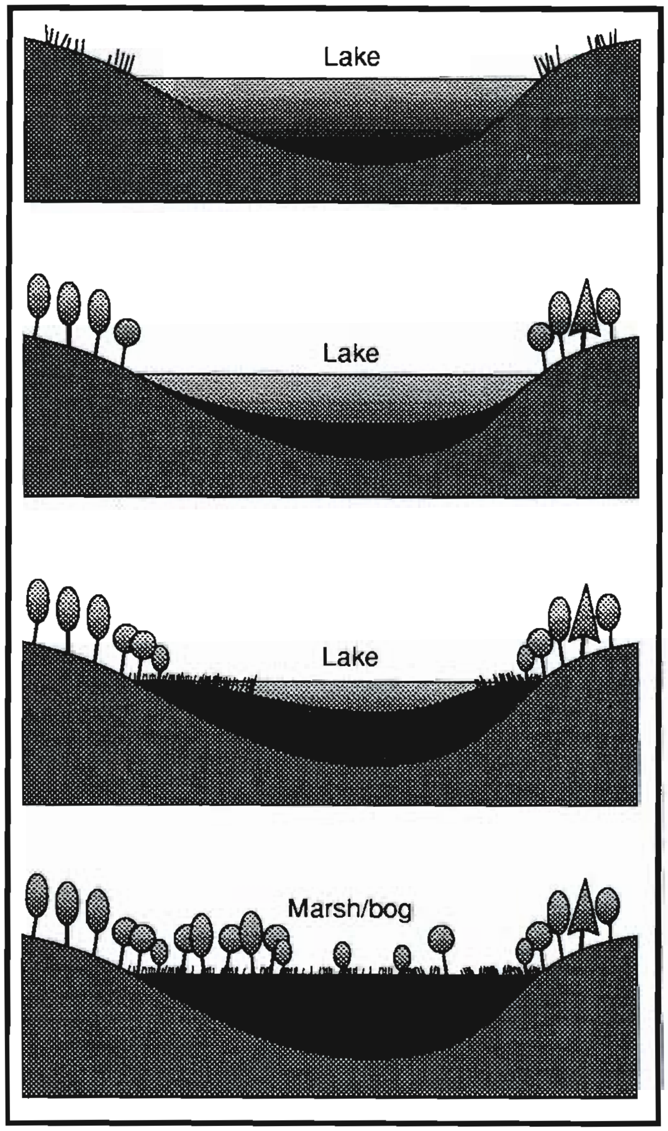
Pollen Study Localities in the Mid-Atlantic Region



(From Gaudreau 1988) Most of the studies have been on lakes or ponds in the Appalachian highlands. The studies in New Jersey and Delaware cover only short time intervals, so that there are gaps in our knowledge of past vegetation and climate.

FIGURE 17

Evolution of a Small Lake into a Bog or a Marsh

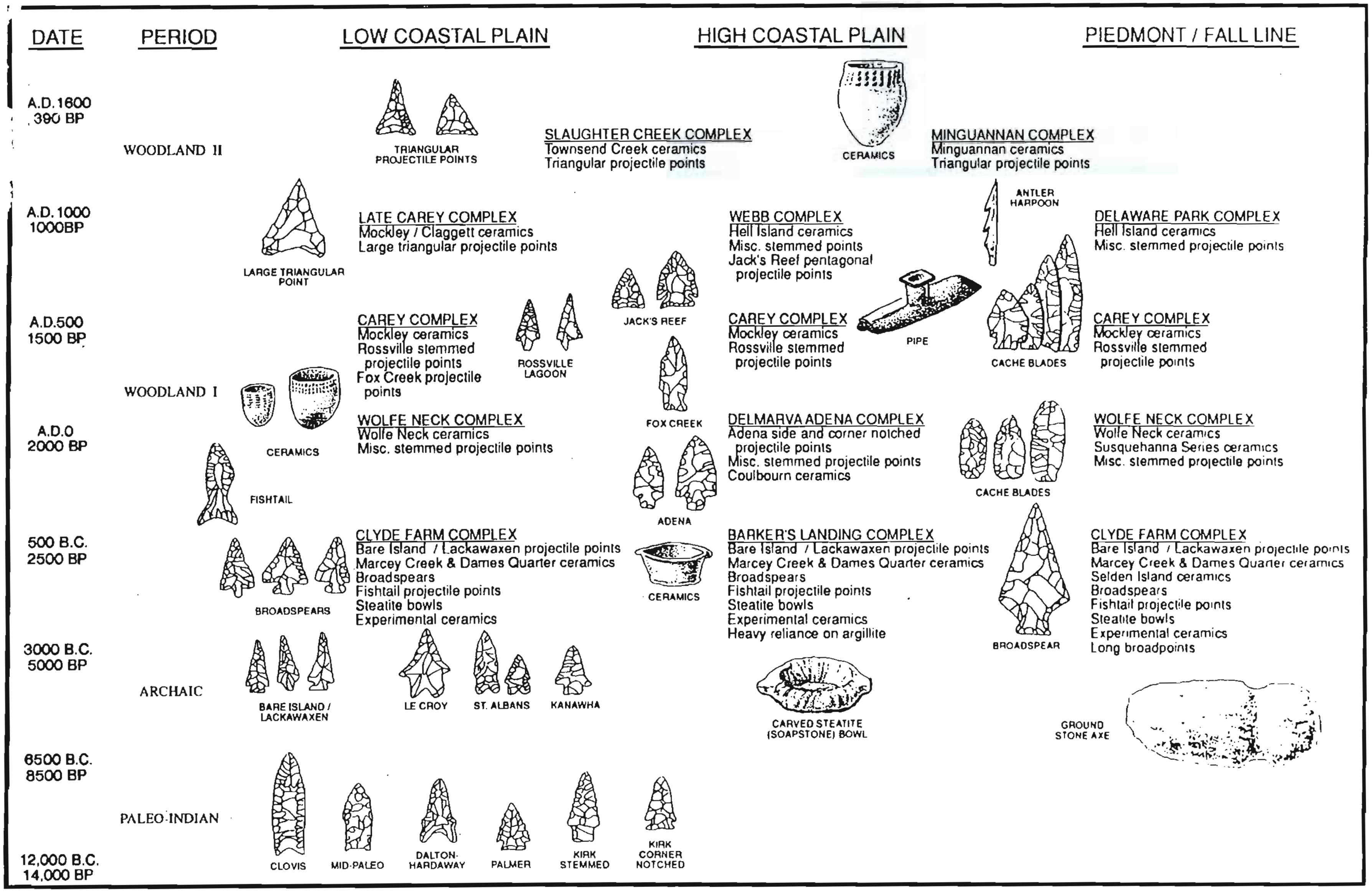


Lakes accumulate sediments carried in by streams and soil erosion, as well as decaying organic matter (leaves and other plant material) (from Whittaker 1975). Through time the lake fills in and a marsh or bog develops. Eventually the former lake may be completely overgrown.

1981), Tannersville Bog and Long Swamp in eastern Pennsylvania (Watts 1979), and Criders Pond in southern central Pennsylvania (Watts 1979) (see Figure 16). There are some difficulties in recreating the prehistoric vegetation of the region based on these studies. Most of the study localities started out as lakes but filled in with mud over time to become bogs (or even dried up for a time) (Figure 17). Some are now overgrown with trees. The pollen preserved in the sediments at the lakes and bogs, thus, represents different proportions of the area around the study site and the developmental history of the localities must be taken into account when interpreting and correlating the pollen and macrofossil information. In addition, most pollen sequences are not well dated. Radiocarbon dating is relatively expensive and usually only one or a few dates are obtained. These problems make it difficult to extend the vegetation and climate reconstruction at one locality to other areas. The discussion that follows is general; details that are important for the Delmarva Peninsula are lacking. The studies presented in this volume help to fill in those details.

TABLE 2

Cultural Complexes and Time Periods of Delaware



For the purposes of the discussion below the last 14,000 years is divided into three parts based on the most broad climate and vegetation trends. The divisions do not necessarily coincide with the divisions of time used by archaeologists in the region (Custer 1984a:30; Custer 1989:36), although some of the changes in prehistoric cultures were influenced by changes in the environment (Table 2).

Post-Glacial: 14,000 - 10,000 BP

Tundra conditions are evident at Long Swamp in eastern Pennsylvania 60 km (38 miles) south of the ice at the maximum of the last glaciation and also in northern New Jersey (Sirkin et al. 1970; Sirkin and Minard 1972). On the southern Delmarva peninsula there is evidence for stands of spruce trees scattered about on grassland and possibly tundra during the maximum of the last glaciation (Sirkin, Denny, and Rubin 1977). Spruce trees were one of the most abundant tree types in the mid-Atlantic forests at about 14,000 BP, and spruce trees were common until about 11,000 BP (Gaudreau 1988; Watts 1983). Regional climate was probably cold and wet, but air masses interacted with ocean currents and the retreating ice-margin creating atmospheric circulation patterns that were much different from the present patterns (Delcourt and Delcourt 1984; Kutzbach 1987).

Another factor to consider is the position of the coast. Between 12,000 and 10,000 BP sea level was much lower than at present, but was rising rapidly (Bloom 1985:220-222). The coast line of the Delmarva Peninsula would have been 100 km (60 miles) east of its present position (Bloom 1985:220-222; Edwards and Merill 1977).

Native Americans first inhabited Delaware sometime after 14,000 BP based on dates from Paleo-Indian period archaeological sites in the east (Custer 1989:81-86). Paleo-Indian peoples probably lived mainly by hunting animals that roamed the shifting woodland and grassland mosaic of vegetation on the landscape at the time. Game animals may have included musk ox, caribou, moose, and the extinct mastodon (Figure 18); however, modern game animals, such as white tailed deer, were also present in the region. Paleo-Indians probably led a wandering existence in small family groups (Custer 1989:95-98). Plant foods were not as important to the diet as later in time, perhaps because Paleo-Indians were relatively new to North America and had not yet learned which plants were useful, and the rapidly changing environments made plant foods hard to predict as they ripened throughout the year.

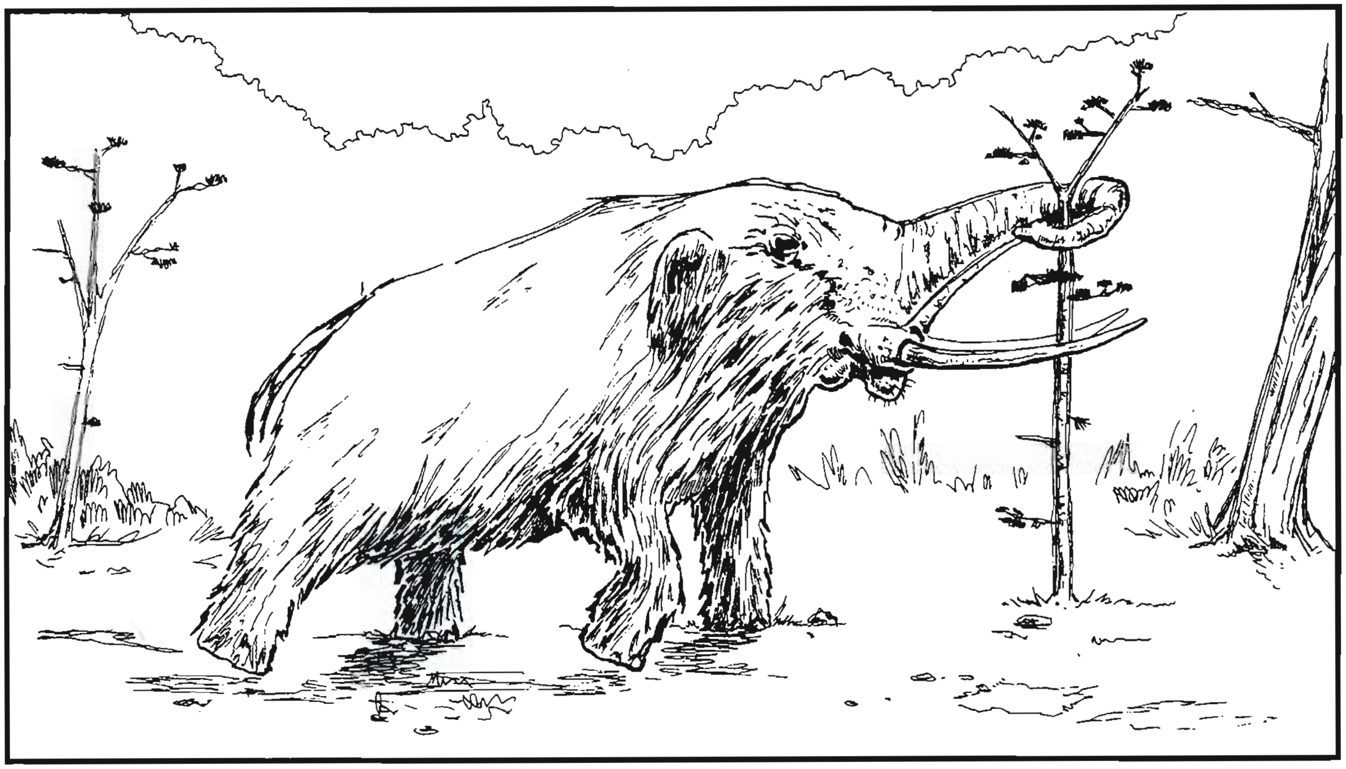
Paleo-Indian period archaeological sites have been found in northern Delaware and are concentrated near Iron Hill in western New Castle County (Figure 19) where there are outcrops of good stone for making tools (Custer 1989:102-109). Another concentration of Paleo-Indian sites occurs along the center of the Delmarva Peninsula where swamps based on poorly-drained soils are concentrated (Figure 19). It is likely that the mosaic of soil types in this area increased the diversity of plants and animals available for exploitation, and that fresh water sources, such as ponds, were more common on the poorly-drained soils. Fresh water became a more critical factor for both game animals and the hunters who stalked them as solar warmth increased. Late Paleo-Indian period sites dating to after 10,000 BP are relatively rare in Delaware and in the mid-Atlantic region in general. The known sites are often small and ephemeral indicating a transitory occupation, and a low population density (Custer 1989:120-121).

Early Holocene: 10,000 - 6,000 BP

The numbers of spruce trees on the landscape had declined in the Middle Atlantic region by 10,000 BP. Spruce and fir trees were replaced largely by pines and oaks (Gaudreau 1988). The somewhat late

FIGURE18

Extinct Mastodon



The mastodon and other large ice-age mammals became extinct before 10,000 years ago because of climate change, and perhaps because Paleo-Indians over-hunted them.

decline of spruce tree populations may have been due to a cool, maritime climate east of the Appalachian Mountains that ended when the Atlantic Oceans's Gulf Stream shifted northward (Delcourt and Delcourt 1984:280).

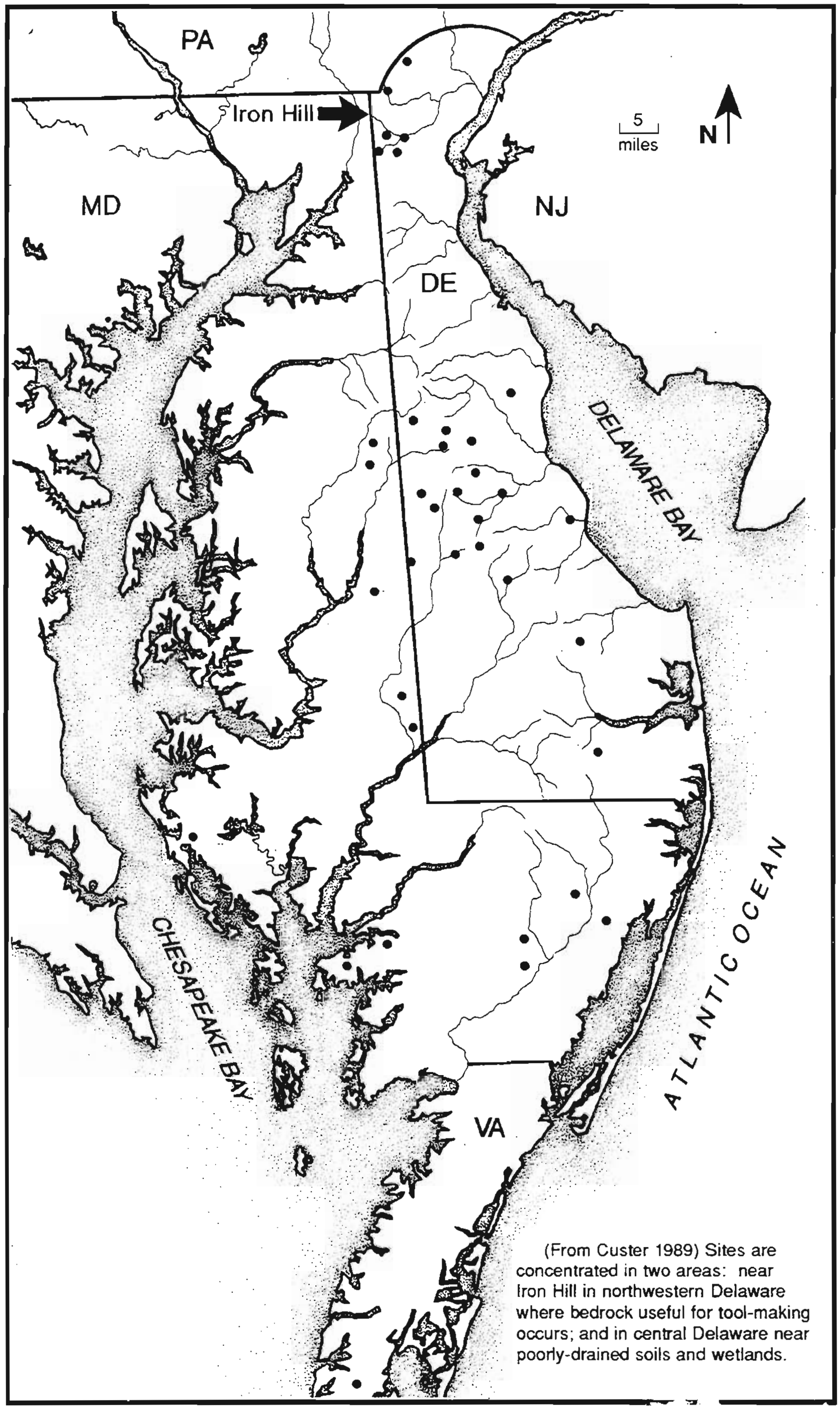
From 10,000 to 8000 BP a mixed forest of pines and oaks dominated the Middle Atlantic region. Oak populations expanded east of the Appalachians after 10,000 BP (Gaudreau 1988). At Rockyhock Bay in North Carolina (Whitehead 1981) water levels had dropped about 10,000 BP. The climate of the Mid-Atlantic region became drier as the edge of the ice sheet retreated north into Canada and as solar warmth increased. Watts (1979:463) concluded that the drier climate along the Atlantic coast and in the Appalachian mountains from before 8000 BP to about 5500 BP was dominated by oak tree species.

The history of pine trees along the Atlantic seaboard is difficult to interpret from the pollen evidence because there are so many different pine species and their pollen is so similar (Gaudreau 1988; Watts 1979:462-463). Gaudreau (1988:238-239) found that three population centers of pines developed between 10,000 and 6000 BP. Each of the areas was apparently dominated by different species of pine trees: southern varieties, northern varieties, and a coastal plain mixture adapted to drier conditions. Watts (1979:462-463) found early migrations of pine species northward, then a drop in pine populations along the mid-Atlantic coast. Finally pine populations expanded again in the late Holocene.

The beginning of the Archaic period in Delaware is marked by major changes in human adaptations (Custer 1989:122). By 8,500 BP solar radiation had reached a maximum and northern species of plants

FIGURE 19

Paleo-Indian Site Distribution on the Delmarva Peninsula



and animals had migrated northward out of the Mid-Atlantic region. Temperate plant and animal species were more common, and climate patterns had become more like those of the present. Few Archaic period archaeological sites have been excavated in Delaware, so what is known is extrapolated from other areas (Custer 1989:127-129). The major change in the archaeology is a wider variety of tools in the Archaic tool kit, especially plant processing tools. Archaic period peoples exploited a wider array of plants and animals than did the Paleo-Indian inhabitants of Delaware. Archaic period sites appear to have been occupied for longer periods of time, perhaps on a seasonal basis by flexible kinship-based groups (Custer 1989:129). Site distribution maps for the Delmarva Peninsula (Custer 1989:132) show that swamp settings were still preferred by people using bifurcate-base type stone points that date to before about 7,500 BP. Exchange of stone tools tied together people across large areas of the eastern United States providing a basis for the more elaborate exchange networks established later (Custer 1989:140).

Middle and Late Holocene: 6,000 BP - Present

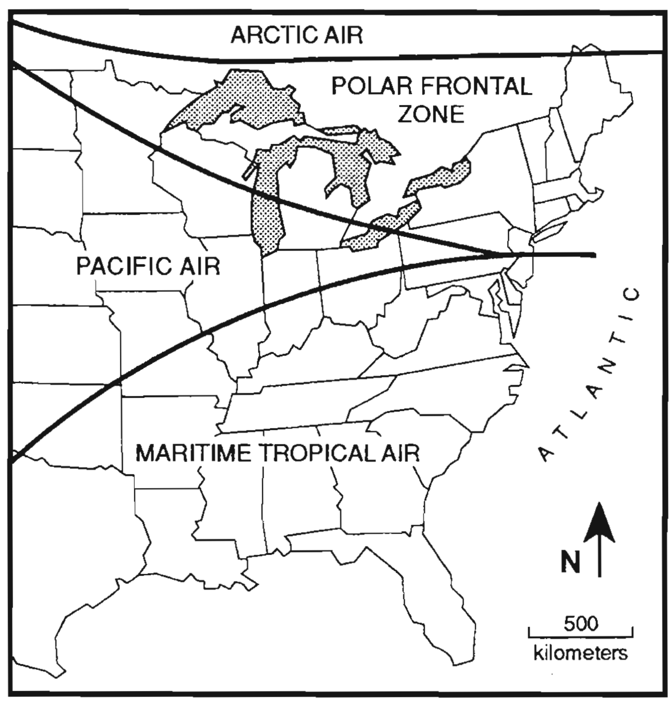
Oak trees remained an important component of the vegetation of the mid-Atlantic region throughout the last 6000 years, but pines were expanding to the south along the Atlantic coast in the last 2000 years (Gaudreau 1988). Southern pines expanded as sea level approached present levels perhaps because water tables rose as well. A cooler and wetter climate also contributed to the expansion of pines after about 5500 BP (Watts 1979). The leaching of soil nutrients on the sandy, well-drained coastal plain may also have favored pines over deciduous tree species in the past 6000 years along the southern Atlantic coastal plain (Watts 1979:463). Hickory, an important species in the present forests of the mid-Atlantic, was a late arrival expanding out of the southeastern U.S. to reach the Delmarva area after 6000 BP (Jacobson, Webb, and Grimm 1987).

Archaeological studies suggest that the climate of the Delmarva Peninsula and New Jersey coastal plain after 5000 BP was quite variable (Curry and Custer 1982; Custer 1989:176-184; Custer and Watson 1987; Stewart 1983). Woodland period archaeological sites have been found buried below wind-blown sediments, which shows that the climate was still relatively dry and forest cover in the region was not complete. Fresh water was apparently a critical resource, so prehistoric people frequently camped near ephemeral ponds (Custer and Bachman 1986b).

The Delmarva Peninsula is in a transitional area between the northeast trending Appalachian highlands and the Atlantic coast and also between broad latitudinal climate zones (Figure 20; see Delcourt and Delcourt 1984; Kutzbach 1987; Watts

FIGURE 20

Present Climate Zones in the Mid-Atlantic



(From Delcourt and Delcourt 1987a) The Delmarva Peninsula is in a transition zone, thus our weather is highly variable, and susceptible to climate change

1979; Jacobson, Webb, and Grimm 1987). The Holocene climate history is difficult to infer from broad regional reconstructions based on pollen studies from swamps on the southeastern coastal plain and bogs and lakes in the Appalachian highlands. The mountain altitudes show their effects on the local climate in the pollen evidence (Gaudreau 1988) and the southern Atlantic coast is dominated by different air masses than the northern mid-Atlantic coast including Delaware (Delcourt and Delcourt 1984; 1987a, 1987b).

Most published studies on vegetation and climate along the Atlantic coast of the United States emphasize the radical changes in climate and vegetation following the end of the last ice age (for example, Delcourt and Delcourt 1984, 1987a, 1987b; Jacobson, Webb, and Grimm 1987; Watts 1979, 1983; Webb, Bartlein, and Kutzbach 1987; Whitehead 1973). Holocene changes are less dramatic and more idiosyncratic and local (Gaudreau 1988; Webb, Bartlein, and Kutzbach 1987). The lack of ideal localities for pollen study on the Middle Atlantic coastal plain, especially on the Delmarva Peninsula and the Jersey coastal plain, leaves a gap in the local vegetation and climate history for the area over the last 10,000 years. A complete Holocene pollen diagram for the coastal plain north of the Dismal Swamp does not, and may never, exist. Thus, many questions remain about the vegetation and climate of the Delmarva Peninsula and New Jersey coastal plain.

The studies contained in this report were carried out to help fill the gap in paleoenvironmental data available for the Delmarva Peninsula and clarify our understanding of the environments in which people lived in the past and in which prehistoric societies developed and changed over the course of centuries. The studies are part of the larger project and more work is being undertaken to provide more detail at locations of intensive prehistoric settlement. Paleoenvironmental reconstructions are constantly being revised and improved as more data becomes available. The reports here are steps along the path to recreating the landscapes of Delaware's past.

The prehistory of the last 5000 years is divided into two archaeological time periods: the Woodland I and the Woodland II. The end of the Archaic period and beginning of the Woodland I at 5000 BP is marked by dramatic changes in prehistoric cultures (Custer 1989:141-144). Archaeological sites of the Woodland I period are more abundant, larger, and more complex than earlier sites. Social organization became more complex with some individuals achieving high status and power. Trade and exchange networks became more formal and more extensive than during the Archaic period. Material culture became more diversified also. First, soapstone bowls and then, ceramics were introduced into the region. A wide variety of chipped stone tools were used. Regional variations in tool kits and life ways are also evident in the archaeology of the Woodland I period (Custer 1989:141-144).

Coastal resources were more intensively exploited in the Woodland period than they had been previously (Custer 1988). The rate of sea-level rise had slowed so that large coastal wetlands could develop and shellfish populations expanded. Tidal streams became the focus of Woodland I settlement, and large clusters of archaeological sites are found below the head of tide along these streams. The State Route 1 corridor crosses several tidal streams near the head of tide and the archaeological sites that are being studied are located there (Custer, Bachman, and Grettler 1987; Bachman, Grettler, and Custer 1988). The studies by Rogers and Pizutto, and by Brush in this volume were conducted along such tidal streams.

The beginning of the Woodland II period is marked by important changes in prehistoric life (Custer 1989:298-300). Settlement patterns changed; trade and exchange networks broke down; and agriculture was introduced. Settlements became more permanent, and the life style was more sedentary. The break down of trade networks is clearly seen in the types of stone used to make tools. Exotic raw materials are rare in Delaware after about AD 1000. Evidence for domesticated plants in Delaware is rare, suggesting that although crops were tended, wild plant foods were still important in the prehistoric diet. A more sedentary life style did allow larger villages to develop and more permanent houses were constructed. Environments during the Woodland II were probably very similar to those of the present.

Native American life was permanently disrupted by contact with European explorers and colonists starting about AD 1600 in the Middle Atlantic (Custer 1989:332-335). Some groups thrived for a time, trading furs and tobacco for European goods, but ultimately disease, political strife, and cultural disintegration ended in the virtual extinction of Native Americans in Delaware.